

REMARKS

Claims 1, 4, 5, and 8 stand rejected under 35 U.S.C. §103(a) as being unpatentable over Forbes in view of Pankove and Chen. Applicants respectfully traverse the rejection. A Declaration of inventor Dr. Munir Nayfeh (hereinafter, “Declaration”) in support of Applicant’s statements herein is respectfully submitted herewith.

Regarding Forbes, the Office Action asserts that Forbes teaches each element of claim 1, particularly particles of uniform size distribution, specifically citing column 4, lines 65-66. In this area, the Office Action states that Forbes states that 1 nm (10 Angstroms) is specifically mentioned as a diameter.

Applicant respectfully submits in response that Forbes does not render unpatentable the pending claims for at least two reasons. One reason is that Forbes does not teach uniform 1 nm silicon nanoparticles at all, but rather teaches a uniform size distribution of particles. The Office Action refers to column 4, lines 65-66, which discloses the uniform size distribution. However, the interpretation in the Office Action of the phrase “uniform size distribution” is incorrect, being contrary to the definition that has been well-established in this record.

The cited section of Forbes specifically teaches nanocrystalline particles having a diameter in the size range or distribution (not size *per se*) of approximately 10 Angstroms to 100 Angstroms, which are in a uniform size distribution. What is a “uniform size distribution”? To determine this in its proper context and as would be understood by those in the art, one should first turn to the patent itself. Please see Declaration, ¶¶17-21. For

example, in the only other section of the Detailed Description specifically describing the size of particles, Col. 4, lines 13-17, Forbes states, “the silicon crystals can be made in a variety of sizes with a uniform distribution in particle sizes by appropriate anneal conditions”. Reading the two sections together, this suggests that either “uniform distribution in particle sizes” is synonymous with “uniform size distribution”, or that Forbes is teaching two different distributions. A reasonable and consistent reading of Forbes’ statements is that the two phrases are synonymous. If they are synonymous, the question then becomes, what does a “uniform distribution of particle sizes”, or alternately stated, a “uniform size distribution”, suggest to those of ordinary skill in the art?

As would be understood by those in the art, a uniform distribution in sizes refers to a distribution wherein the possibility that a particle is a particular size within the stated range would be about the same as the possibility that the particle would be a different size within that range. This is a clear, reasonable reading of both the phrase “uniform size distribution” and the phrase “uniform distribution of sizes”. It also is perfectly consistent with the fact that the particles disclosed in Forbes are always described in terms of a range, and never in terms of a particular particle size. This is true whether in the specification (see col. 4 and the Abstract, e.g.) or in the claims (see claims 3, 9, 16, 20, and 22).

The Office Action asserts that in Forbes, 1 nm or 10 Angstroms is specifically mentioned as a diameter. However, the 10 Angstroms size is always mentioned in the context of, and as part of, a size range. Forbes is not believed to teach a specific 10 Angstrom diameter alone, nor, for that matter, does it teach a specific 100 Angstrom diameter

alone. Further, the specification of Forbes is not believed to enable uniform 1 nm silicon nanoparticles. Please see Declaration, ¶22. Instead, it teaches particles having a general diameter within a range of approximately 10 Angstroms to 100 Angstroms, which may be formed by implanting or depositing silicon into a gate oxide and annealing. One of ordinary skill in the art would appreciate that it would be very difficult to use annealing to produce uniformly-sized particles, or to produce particles of a predetermined size. This is another likely reason why the particles in Forbes are described only in terms of a general range.

The interpretation also is consistent with the general understanding of the phrase “uniform distribution” as previously submitted by Applicant. The Office Action states that, “the uniform size distribution is desirable to obtain uniform tunneling”. However, Forbes does not appear to teach a method for forming uniformly-sized particles. Instead, it appears to teach the opposite. No evidence has been presented that the phrase “uniform size distribution”, particularly in context with the phrase “uniform distribution of particle sizes”, would be interpreted by those of ordinary skill in the art as meaning that the particles are of uniform size.

The Office Action appears to conclude that certain mechanisms can produce particles of uniform size, where particle size depends primarily on reaction temperature, but apparently relies on one of only three sources to support this reasoning: official notice, Chen, and Pankove. There appears to be no support in the record or the art that is specifically cited for the Examiner’s understating of “uniform size distribution”. Again, to the extent

official notice is being relied upon by the Examiner, Applicant respectfully traverses and requests additional citation. Applicant will now address the citation of Chen and Pankove.

The Office Action cites Chen and Pankove as suggesting formation of uniform-sized particles. Chen specifically defines a “nanocrystal” as being confined in three dimensions (height, width and depth) equal to or less than 40 nm, which is a very wide range. See col. 4, lines 15-19. According to Chen, in the embodiment of FIGs. 1 and 2, within or on a layer 30, a nanocrystal 1 to 2 nm thick (note that only thickness is defined here, versus the general definition in Chen of a “nanocrystal”) can be formed. However, FIG. 2 specifically shows that the same nanocrystal 34 has length and width dimensions of 20 nm and 8 nm. Further, even the thickness dimension is provided as a range, which teaches away from a uniform-sized nanoparticle. This also suggests that Chen fails to teach or suggest uniform 1 nm silicon particles. Please see Declaration, ¶¶23-26.

Though Chen teaches 1-2 nm thick nanocrystals 34 in one embodiment, it also teaches a different embodiment including nanocrystals in FIG. 9. However, Chen fails to teach or suggest that this alternative embodiment includes uniform 1 nm nanoparticles. Based on the appearance, apparently, of FIG. 9, the Office Action assumes, without citing supporting evidence, that the drawing is to scale, even though the MPEP specifically provides that drawings are not assumed to be scale (and even though, somewhat incongruously, the Office Action apparently assumes that FIGs. 1 and 2 are not to scale, because they clearly depict a nanocrystal 34 with linear dimensions significantly greater than its thickness).

Additionally, based on FIG. 8 (of which FIG. 9 is a cross-section) of Chen and the quantum dots shown therein, it is clear that the dots 34 are cylindrical in shape, and it is very likely that the nanocrystal is significantly larger than 1-2 nm along dimensions other than thickness. Moreover, there is a strong indication that the drawings are not to scale. For example, dimensions of the nanoparticle film other than the thickness are explicitly given (column 7, line 43) to be 0.4 micrometer and 20 micrometers (or 400 nm and 20,000 nm). Chen further states that nanocrystals or quantum dots in one of the two-dimensional arrays may have a density of 10^{12} cm^{-2} . This density corresponds to 10^6 cm^{-1} , and is consistent with having 40 nanoparticles along the width and 2,000 particles along the length. However, FIGs. 8 and 9 show only three particles along the width and twelve along the length, which indicates that they are not to scale, nor are the particles shown in a ratio of 0.4 : 20. If 400 are there, then the center-to-center particle interspacing is 10 nm. A reasonable estimate is that the particle size is about 5 nm.

Still further, nanocrystals 34 in Chen are specifically defined as particles confined in three dimensions by up to 40 nm. Thus, to reach the conclusion made in the Office Action, one also has to cite the 1-2 nm thickness of a nanocrystal 34 in one disclosed embodiment of a broadly defined nanocrystal, ignore the length and width dimensions also cited with respect to that same nanocrystal, and assume, without any evidence, that this nanocrystal is also shown in a separate embodiment, as shown in FIG. 9.

Moreover, in the studies of Chen the staircase voltage of the threshold as a function of the gate voltage was measured at liquid nitrogen temperature of -77 centigrade,

which is an indication that the device is not yet a room temperature device. In addition, the staircase structure is barely resolved even at this low temperature. These observations are consistent with nanocrystals whose width and length of are comfortably larger than 1-2 nm (of the order of 5 nm).

To the extent the Office Action is relying on the use of the common reference character 34 to make this connection, Applicants note that a “nanocrystal” 34 is specifically defined in Chen as being limited by all three dimensions to 40 nm. Thus, the reference character 34 in FIG. 9 should only limit the size of the nanocrystal to 40 nm, not 1-2 nm. Further, there is no support for the assertion that the 1-2 nm thick nanocrystal in FIGs. 1-2 is likewise confined in the other dimensions to that degree, and there is strong support (see FIG. 2) indicating otherwise. Thus, the Office Action is not believed to have established that the single 1-2 nm dimension in a single embodiment can be selected and extrapolated for all three dimensions and further applied to a different embodiment, as these conclusions are apparently based only on a drawing (not to scale) and the “34” reference character, which limits the three dimensions of a nanocrystal only to 40 nm.

As for Pankove, a 10 Angstroms dimension is cited in col. 5, lines 5-6, but only for diameter and depth. However, this is not the same as a 1 nm silicon nanoparticle as claimed. Please see Declaration, ¶34. The present application defines nanoparticles confined by approximately a 1 nm diameter in all directions. This is why a single dimension (diameter) is used. Pankove, by contrast, specifically defines cylindrical particles (col. 4, line 66-col. 5, line 1), having a diameter and a depth. Please see Declaration, ¶¶27-30. This

description does not confine the particles along all dimensions by 1 nm, as in a spherical particle. Please see Declaration, ¶¶33-34. In fact, a cylindrical particle of 10A diameter and 10A depth has a corner-corner dimensional length of 14.14 A, or 1.414 nm. The spherical particles of the present invention, by contrast, can be defined by a single dimension, diameter. Please see Declaration, ¶31. Thus, Pankove also fails to teach, suggest, or enable the uniform 1 nm silicon particles claimed.

Applicant further submits that neither Forbes, Chen, nor Pankove enable a method of producing uniform, 10 Angstrom silicon nanoparticles. Forbes teaches that a range of particle sizes can be produced by appropriate anneal conditions, but Applicant submits no evidence is provided that such anneal conditions would or could result in uniform 10 Angstrom nanoparticles. Please see Declaration, ¶21. Because Forbes can reasonably be interpreted to teach a range of particle sizes, and not a uniform size, Applicant's submissions regarding the teaching of Forbes in this regard do not contest the validity of the patent, as has been suggested in prior Office Actions, but they dispute an interpretation of the patent wherein uniform 10 Angstrom particles are enabled by Forbes. The disclosure of Forbes itself does not appear to specifically teach a method for producing nanoparticles beyond a general statement that "appropriate anneal conditions" should be used.

The fact that a uniformly-sized particle would be desirable in the art (though Forbes does not appear to explicitly teach such a need, but rather the need only for particles in a particular range) does not itself enable, nor render obvious, the actual production of such

silicon nanoparticles. The Office Action appears to be relying on official notice to support this conclusion, which is traversed by Applicant.

To the extent the Office Action is relying on Forbes, Pankove, or Chen, Applicant respectfully submits that none of these references enable production of uniform 1 nm silicon nanoparticles, as defined. Accordingly, Applicant respectfully requests reconsideration and withdrawal of the rejection.

The Office Action rejects claims 5-7 under 35 U.S.C. §112, first paragraph, stating that these claims are not enabled for the reason that single particle tunneling has not actually been shown, and would require undue experimentation to produce. Alternatively, the Office Action submits that the subject matter of claims 5-7 are not supported by the written description in the application, because “in an unpredictable art, merely sketching a diagram of a desired phenomenon is not enough to allow one of ordinary skill to accomplish the desired end”. Claim 5 defines, particularly, a method for operating a single electron device, which has a source, a drain, a gate, and 1 nm diameter silicon nanoparticles implanted as a buried gate layer, comprising: creating at least one hole in the silicon nanoparticles to enable the silicon nanoparticles to conduct a single electron at room temperature across the source and the drain; and applying a voltage across the drain and the source. Thus, an enabling written description that describes this method would support claim 5.

Applicant respectfully submits that this method is indeed clearly described, and enabled, by the description of the experiments set forth in the application. Please see Declaration, ¶¶39-52. The Office Action states, “merely sketching a diagram of a desired

phenomenon is not enough to allow one of ordinary skill to accomplish the desired end”. However, the experiments described in the application clearly show an experimental configuration of what is referred to in the art as a two-terminal device showing conduction of a single electron, and a voltage applied to a source, but is used in the art to demonstrate features of the operation of a three-terminal device. The specification also describes how the experiments conducted used irradiation to manipulate and control a gate, namely the nanoparticles.

Particularly, comparing the claim features to the specification, claim 5 defines a single electron device. Page 6, line 26-page 7, line 1 specifically states that single electron operation has been experimentally demonstrated. Please see Declaration, ¶45. Claim 5 defines a source, a drain, and a gate. Page 7, lines 8-9 specifically states that tip 12 acts as the source, and substrate 16 acts as the drain, while silicon nanoparticle film material 14 having 1 nm silicon nanoparticles 18 represents the quantum well (which models action of an FET transistor). Please see Declaration, ¶¶46-50.

Claim 5 further defines creating at least one hole in the silicon nanoparticle to enable the silicon nanoparticle to conduct a single electron at room temperature across the source and the drain. As submitted in the Declaration, the experimental setup described is a standard setup known to those of ordinary skill in the art for testing single electron operation. The background of the present application describes an analogous experiment, in which researchers controlled the movement of single electrons into and out of minute blobs of indium by manipulating the voltage applied to a tip and a substrate. This experiment is

described as a single-electron switch, a single electron device, and explicitly, a transistor. Please see Declaration, ¶40. Further, the indium film constitutes a non-controllable gate (since there is no direct metal contact), and is referred to specifically as a “gate”.

The experimental setup described and shown in the present application provides a non-contact “floating” gate with silicon nanoparticles. Please see Declaration, ¶50. Irradiation of the silicon nanoparticles creates and manipulates externally the necessary charge vacancies for single electron operation. Though there is no direct metal contact in the experimental configuration, the radiated electric field delivered by light radiation or a laser beam constitutes a non-contact manipulator, which would be understood in the art to be a controlled gate for the single electron device. This experiment would be appreciated by those of ordinary skill in the art to demonstrate single electron operation for a single electron device, and/or for a transistor. Please see Declaration, ¶49.

Additionally, page 8, lines 11-14, states that the measured spacing of the steps (progression of resonance) is consistent with the characteristic single electronic charging, and after stimulation of the nanoparticle 18 from a mercury lamp, a second regular step structure is provided. Page 9, lines 10-15, describes the phenomena in terms of hole generation. Page 8, line 25-page 9, line 2, describes the phenomena in terms of opening of tunneling channels. Claim 5 also defines applying a voltage across the drain and the source. Page 7, lines 15-26, describes varying a voltage between the tip and the (grounded) substrate, and recording the tunneling current, and two sets of I-V spectra are provided in FIGs. 2 and 4 (with derivatives shown at FIGs. 3 and 5).

Thus, the features of claim 5 (as well as claims 6 and 7, see page 8, lines 15-24) are clearly provided in the application and supported by the experimental data provided in FIGs. 2-5, as interpreted by the theory set forth in pages 6, line 17-page 9, line 26. Absent evidence that Applicant's data or interpretation thereof is incorrect, both written description and enablement of the subject matter of claims 5-7 is clearly provided. Please see Declaration, ¶¶38-54. To the extent the Examiner disagrees with Applicant's experimental data or interpretation thereof, evidence and clear reasoning supporting such disagreement and detailing the flaw in the experimental protocol is respectfully requested.

As shown, therefore, the experiments described in the present application illustrate the method claimed. The "sketching a diagram", as described by the Examiner, illustrates one exemplary implementation of such a method. However, the method itself is clearly described and enabled by the experiments shown. One skilled in the art would understand that the described experiments perform each of the steps of the claimed method.

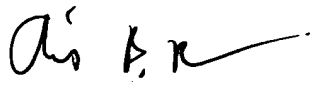
Claims 6-7 stand rejected as being obvious over the previous references cited, and further in view of Matsumura. Applicant respectfully traverses for the reasons stated above regarding the failure of Forbes, Pankove, and Chen to teach and/or enable uniform 1 nm silicon nanoparticles.

The Examiner has indicated that claims 9-12 are allowed. Applicant acknowledges and appreciates this statement. At this time, Applicant elects to keep claim 2 in its current form pending the Examiner's reply to the response herein.

For at least the foregoing reasons, Applicant believes that this case is in condition for allowance, which is respectfully requested. The Examiner should call Applicant's attorney if an interview would expedite prosecution.

Respectfully submitted,

GREER, BURNS & CRAIN, LTD.

By 
Arik B. Ranson
Registration No. 43,874

Customer No. 24978

December 29, 2004

300 South Wacker Drive
Suite 2500
Chicago, Illinois 60606
Telephone: (312) 360-0080
Facsimile: (312) 360-9315
P:\DOCS\1201\63407\702125.DOC